Satellite Image Classification using Clustering Algorithms with Edge Detection Operators

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Abstract— Image classification consists of image processing algorithms for grouping cells of similar characteristics together. Satellite image classification is essential to extract the information and identify the different components such as water dense region, roads, vegetation etc. from the classified image. In this paper, an attempt is made to locate and identify the different regions of interest using classification algorithms such as K means and Fuzzy-C Means. Comparison is done for both the algorithms in terms of computational time and memory requirements. Also, the algorithms are applied for the input image by considering different values of K and its discussion is presented in the paper. The algorithms are then applied for the given image with edge detection operators to obtain the better visual clarity of the edges.

Keywords- K-Means, Fuzzy C-Means, Edge Detector, clustering, computational time, memory utilization.

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I. INTRODUCTION

Digital image processing involves processing of digital images. Processing of digital images can be low level, mid-level or high level depending on the application. Some of the important applications of image processing include computer vision, face detection, forecasting, optical character recognition, remote sensing etc.

Remote sensing applications involve representations of the parts of the earth as seen from space. Satellite images can be acquired using electronic sensors like passive (which measure the reflected sunlight or thermal radiation) and active sensors (which make use of their own source of radiation). The images taken are usually in multi-layered form where each layer represents an image acquired at a particular wavelength band. Based on the number of layers, they can be classified into multi-spectral (few image layers), super-spectral (large number of layers), and hyper spectral (hundred or more contiguous bands). Satellite images are thus an indispensable tool in scientific research, and their application in remote sensing involves Earth observation, Agriculture, Defense and weather prediction. One of the major applications in remote sensing is image classification and clustering.

Image Classification and Clustering

Image classification is the most important part of digital image analysis. It includes a broad range of approaches to the analyses of numerical properties of various image features and organizing data into categories. The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or themes. The purpose of image classification is to label the pixels in the image with meaningful information of the real world for better and useful information extraction. Satellite image classification can be used to obtain information such as cadastral data, land cover type, vegetation type, etc. In image clustering, we do not know the characteristics and similarity of data in advance. Using statistical concepts, we split the datasets into sub-data sets such that each of the sub-dataset has similar data [15]. No training sets are used in this case.

The two main classification and clustering methods are Supervised Classification and Unsupervised Classification. The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data. Using this method, the analyst has available data and sufficient known pixels to generate representative parameters for each class of interest. This step is called training. Once trained, the classifier is then used to attach labels to all the image pixels according to the trained parameters. With supervised classification, we identify examples of the Information classes (i.e., land cover type) of interest in the image. This is used in cases where large amount of information is available in an area to be classified.

In applications where there is less information in an area to be classified, only the characteristics of the image are used. Multiple groups from randomly sampled data, will be divided into homogeneous classes using a clustering technique. This classification technique is called unsupervised classification. Pixels are grouped based on the reflectance properties of pixels. These groupings are called “clusters”. The user identifies the number of clusters to generate and which bands to use. The unsupervised type of image classification technique is commonly used when no sample sites exist.

All classification algorithms are based on the assumption that the image in question depicts one or more features and that each of these features belongs to one of several distinct and exclusive classes. There are different image clustering algorithms like k-means, fuzzy c-means, filtered cluster etc. K-Means and Fuzzy C-Means (FCM) are the most popular algorithms and are chosen for experimentation due to the scope of automatically determining the value of k for any input image. But in this paper we focus on choosing various values of k and comparing the results in each case.

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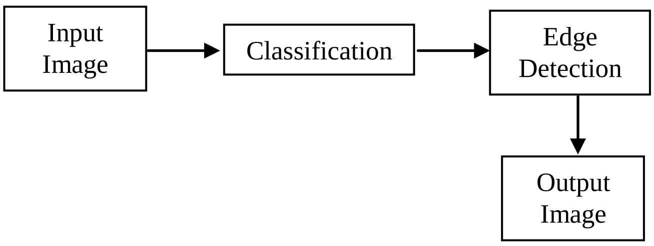
II. LITERATURE SURVEY

D.Lu and Q.Weng et.al discuss about the current practices, problems and prospects of image classification. Unsupervised K-means clustering algorithm has been used to partition the image into a number of spectral classes based on the statistical information inherent in the considered image [1]. Chinki Chandhok and Soni Chaturvedi et.al have introduced a new approach for image segmentation by applying k-means algorithm. Various initial partitions result in different final clusters. A framework of unsupervised clustering of images based on the colour feature of the image has been proposed which shows intra-cluster variance, but does not ensure that the result has a global minimum of variance [2]. Yinghua Lu and Tinghuai Ma et.al have put forward an improved fuzzy c-means algorithm and applied to deal with meteorological data samples on top of the traditional fuzzy c-means algorithm. It has been demonstrated that the number of iterations and cluster centers are significantly less as compared to K-means algorithm [3]. Dilip Kumar and Sanjib Chandra et.al have compared the performance of FCM algorithms on 4 data sets, in terms of the quality of the clusters obtained. After mapping the clusters into 2-D for visualization using a self-organizing map (SOM), the quality of clusters and computational time for each of the clusters has been analyzed for various data samples [4]. Juraj Horvath has implemented segmentation method based on region growing and has used membership grades of pixels to classify pixels into appropriate segments. Number of segments formed and the size of segments on each of the samples were compared and it was found that the segments formed do not have borders for accurate segmentation analysis [5]. Anita V Gawand and Prashant Lokhande et.al have implemented both k-means and fuzzy c-means algorithms. Analysis of the output has resulted that K-means clustering algorithm is inherently iterative, with no guarantee that it will converge into an optimal solution. Fuzzy c-means on the other hand, is not very adequate for noisy images [6].

Rashmi, Mukesh Kumar, Rohini Saxena et.al have studied various edge detection techniques such as Prewitt, Robert, Sobel, Mass Hildrith and Canny operators. It has been concluded that canny edge detector performs better than all the other edge detectors on various aspects such as- it is adaptive in nature, performs better for noisy images, gives sharper edges and low probability of detecting false edges [7]. Dr. S Vijayarani and M Vinupriya et.al have used canny edge detection and sobel edge detection algorithms to extract edges from facial images. Performance factors like accuracy and speed have been analyzed using a confusion matrix. It was concluded that canny edge detection algorithm produces higher accuracy in edge detection and execution time as compared to Sobel [8]. Raman Maini and Dr Himanshu Agarwal have demonstrated the comparative analysis of various Image Edge Detection techniques. The author also discusses that the use of canny method is better than all the other algorithms, but computationally more expensive [9].

The paper is organized as follows. Section 1 contains the introduction to image processing and satellite images. Section 2 contains the literature survey and review of other papers. Section 3 contains the methodology adopted for image classification and edge detection. Section 4 includes the environment used for implementation. In section 5 we compare, discuss and analyse the results. And lastly, section 6 we draw the conclusions and state the scope for further work.

III. METHODOLOGY



After a thorough Literature Survey, it is found that K-Means and Fuzzy C-Means (FCM) algorithms are popular because of their various advantages. Hence these two algorithms are considered for further discussion and experimental analysis. The outputs of K-Means and FCM algorithms will not identify the edges distinctly and hence edge detection algorithms are applied to the output of classification.

A. *K-Means Clustering*

K-means is one of the simplest unsupervised learning algorithms that solves the well know clustering problem. It finds a partition in which objects within each cluster are as close to each other as possible and as far from objects in other clusters as possible. [1][2][6]

Algorithm-

1) Read the image as input.
2) For separation of the colours in the image apply de-correlation stretching.
3) Place K points into the space represented by the objects that are being clustered in the input image. These points represent initial group centroids. The user can define the value of k based on the image complexity.
4) Assign each object to the group that has the closest centroid.
5) For each data point x_i, compute its membership m (c_j /x_i) in each centre c_j and its weight as w(x_i).
6) For each centre c_j re-calculate its location from all data points xi according to their membership and weights.
7) Repeat the steps 5 and 6 until convergence i.e the change in coefficients between 2 iterations is no more than a threshold value. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.

The algorithm aims at minimizing an objective function. In this case a squared error function isconsidered as objective function. The objective function is given by-

$$\sum_{j=1}^{k}\sum_{i=1}^{x}\left\|x_i^{(j)} - c_j\right\|^2$$

Where $\left\|x_i^{(j)}-c_j\right\|^2$ is a chosen distance measure between a data point $x_i^{(j)}$ and the cluster centre c_j, is an indicator of the distance of the data points from their respective cluster centres.

B. *Fuzzy C-Means Clustering*

The FCM algorithm is one of the most widely used fuzzy clustering algorithms. FCM is able to determine, and update the membership values of a data point with a pre-defined number of clusters. It is an algorithm which allows one piece of data to belong to two or more clusters. Fuzzy C Means is a soft clustering technique and provides a more precise computation of the cluster membership and has been used successfully for image clustering applications like geological and satellite images. [2][4][5][6]

It is based on minimization of the following objective function:

$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m}\left\|x_i-c_j\right\|^2 \qquad , 1\leq m< \infty$

Where-

- m is any real number greater than 1.
- u_{ij} is the degree of membership of x_i in the cluster j
- xi is the ith of d-dimensional measured data
- cj is the d-dimension centre of the cluster
- $\|*\|$ Is any norm expressing the similarity between any measured data and the center.

Algorithm

1) Initialise the fuzzy parameter with a constant value greater than 1, the number of clusters and the stopping condition (when $max_{ij}\left|u_{ij}^{k+1}-u_{ij}^{k}\right|$ is between 0 and 1).
2) Set the initial loop counter variable k=0.
3) Calculate the different centroids (using the above function) and the objective value j.
4) For every pixel that is associated with the cluster, compute the membership values.
5) If the objective function's value between consecutive iterations is less than the stopping condition, then stop otherwise set k=k+1 and go to step 4.
6) Repeat the same, till convergence (that is, the change in coefficients between two iterations is no more than the given sensitivity threshold).This results in de-fuzzification of the membership values.

C. *Edge Detection*

A large number of studies have already been carried out in the field of edge detection for images [16] thus stating its importance within the field of image processing. A good edge detector is the one which is able to detect edges for any type of image and shows higher resistivity to noise. In this paper we propose clustering techniques to be applied before edge detection in order to obtain distinct edges and to enhance segmentation results. The clustering algorithms highlight similar classes and the edge detectors identify the real object boundaries as edges. There are a large number of edge detectors available, each designed to be sensitive to certain kinds of images. In this paper we shall be using Sobel, Canny, Prewitt, Robert Cross and LoG (Laplacian of Gaussian) operators for study and analysis. The convolution masks used for various algorithms are-

$$Gx=\begin{bmatrix}-1 & 0 & +1\\ -2 & 0 & +2\\ -1 & 0 & +2\end{bmatrix}*A \quad Gy=\begin{bmatrix}-1 & -2 & -1\\ 0 & 0 & 0\\ +1 & +2 & +1\end{bmatrix}*A$$

Sobel operator

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Prewitt operator

$$Gx=\begin{bmatrix}-1 & 0 & +1\\ -1 & 0 & +1\\ -1 & 0 & +1\end{bmatrix}*A \quad Gy=\begin{bmatrix}-1 & -1 & -1\\ 0 & 0 & 0\\ +1 & +1 & +1\end{bmatrix}*A$$

Canny operator

+1	0
-1	0

Gx

0	+1
-1	0

Gy

Robert Cross operator

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

LoG operator

Fig. 1- Convolution mask for different Edge detector operators

IV. IMPLEMENTATION DETAILS

Based on the methodology adopted in section 2, the experiments are conducted for various set of input satellite images with different dimensions, resolutions and file formats. The sample images considered are displayed in Fig 2. The experiments are conducted for images ranging from simple to complex. The meaning of simple image in the sense that it has less features to classify whereas complex images has more features for classification. The experiments are conducted using MATLAB R2010a at Centre for Small Satellite Design, NMIT Campus. The comparison of algorithms is done based on HVS measures, computational complexity and memory requirement. The computational complexity is measured in terms of computational time for k-means and fuzzy c-means with and without edge detector operators. Considering 2(c) as the input image and number of clusters as 3, the computational time without using edge detection operators is 1.51sec. After using edge detection operators, the computational time was found to be 1.765sec. The memory requirement is measured based on the memory required to fit the algorithm. For the same input imageand k value, the allocated memory was found to be 184558Kb. The details of the images considered are displayed in Table 1.

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(a) (b) (c)

Fig. 2- Various input images considered

Table. 1: Details of different images considered

Input Images	Dimension	Resolution	Format	Size in kb
Fig. 2a	**266x190**	**96dpi**	**JPEG**	**12.9**
Fig. 2b	**259x194**	**96dpi**	**JPEG**	**13.6**
Fig. 2c	**225x225**	**96dpi**	**JPEG**	**18.8**

V. EXPERIMENTATION RESULTS AND DISCUSSION

The experiments are conducted for image shown in Fig 2(a), 2(b), and 2(c) using K-Means algorithm by choosing value of k as 2, 3 and 4 respectively. The corresponding results are displayed in 3(a), 3(b) and 3(c). Also Fig 4 indicates the computational time required and Fig 5 shows the memory requirements for different values of k.

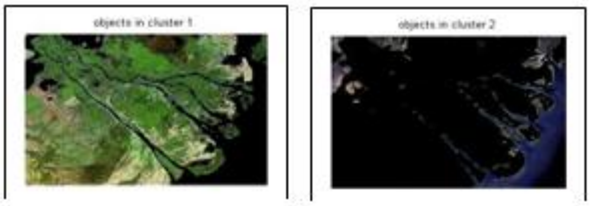

Fig 3a: Outputs of clustering for k=2 for image 2(a)

The experimental analysis indicates that the k=2 is sufficient for the given input image 2a because it has only 2 features such as Land and Sea to classify. Applying k=3 and 4 for this input image generates many random clusters and it is difficult to identify the significance of each cluster. Also, choosing k=2 reduces the computational complexity and the memory utilized as discussed in the later part of the paper.

Fig. 3b- Outputs of Clustering for K=3 for image 2(b)

When the same value of K is applied for the input image 2b, the results are not satisfying as there are three features in the image, namely Vegetation, Buildings and Water body, and we obtain only two clusters (The vegetation and buildings are present in the same cluster). Thus we cannot obtain all the features distinctly. K=3 is required for the input image 2b because the complexity of the image is higher. The computational time and memory utilisation also increases, but all the required features are obtained from the image. When experimentation is done with K=4, we obtain more features than the requirement. Many clusters are formed and it cannot be identified as to what each cluster represents. Further, it becomes computationally more expensive in terms of time and memory.

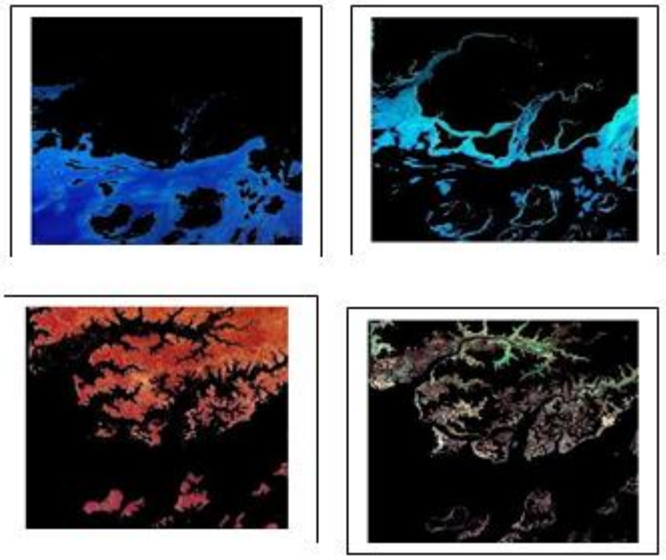

Fig. 3c- Outputs of clustering algorithm for K=4

However, K=4 is required for image 2c as it is a complex image. Detailed features such as Deep waters, Shallow Rivers, Hard land and marshy areas around the water bodies can be observed and analysed after clustering. When K=2 and 3 are applied for this input image, we do not obtain all the features of the image distinctly and the results are not satisfying. Even though K=4 takes much more time and consumes more memory than for k values 2 and 3, each detail in the image will be classified properly.

Thus, it can be said that, as the image complexity increases, larger values of k is required for effective clustering and it is very important to determine the suitable value of k for the input images.

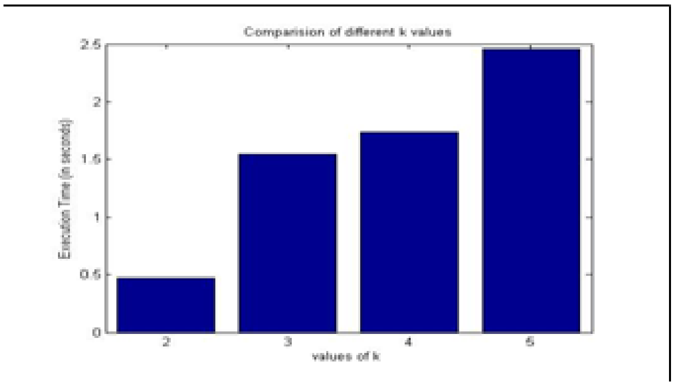

Fig. 4- Computational time for various values of k

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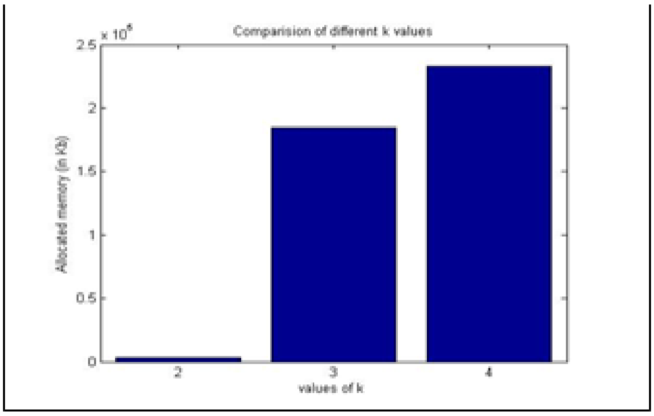

Fig. 5- Memory allocated for various values of k

Fig 4 and 5 indicate the computational time and memory required for the execution of K-Means algorithm. It is evident from the result that computational time and memory increase with the increase in the value of k.

Since edges cannot be clearly identified using clustering algorithms, we apply edge detection operators to obtain distinct and clear edges for the classified images. The results of various edge detection operators after applying it on the K-Means classified image with k=3 is displayed in Fig 6.

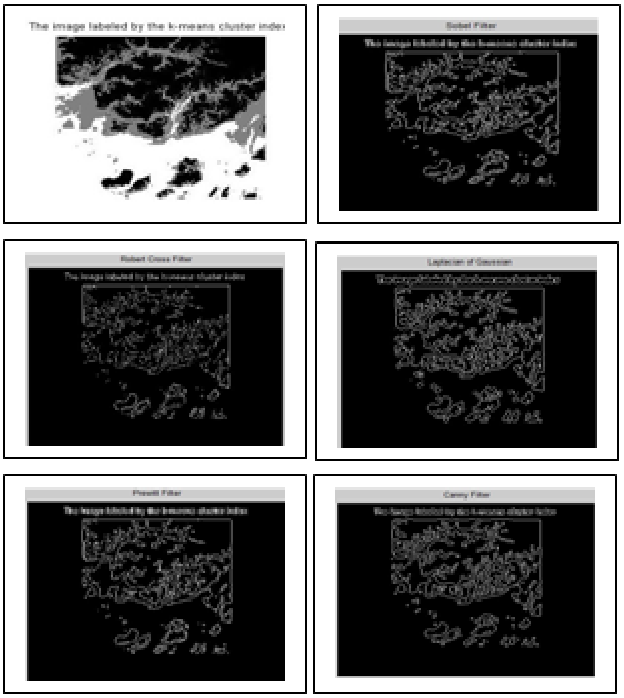

Fig. 6- Various edge detection operators applied on input image

Experiments are now conducted for images shown in 2a, 2b and 2c using Fuzzy C-Means (FCM) algorithm for 2, 3 and 4 initial clusters respectively. It was observed that similar outputs are obtained after FCM classification. Since HVS results are almost similar, focus is given to computational time and memory. Fig 7 indicates the computational time required and Fig 8 shows the memory requirements for various initial cluster values.

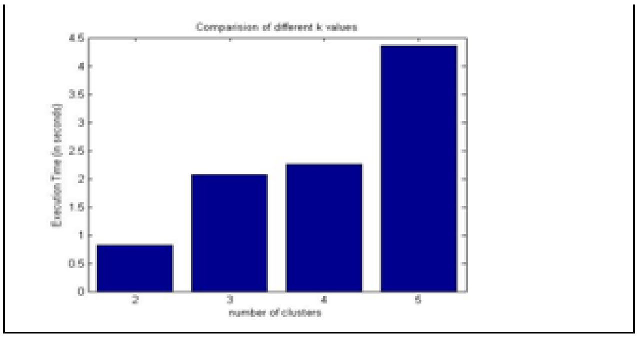

Fig. 7- Computational time for various values of k

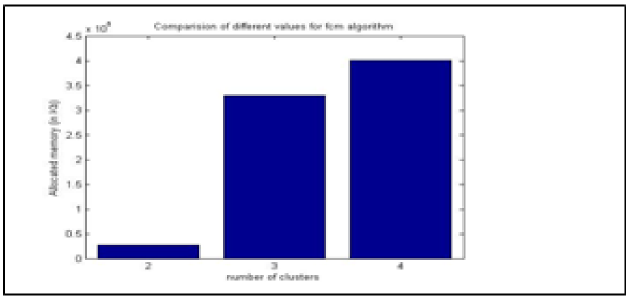

Fig. 8- Memory allocated during clustering for various values of k

Similar to K-Means algorithm, the results in fig 7 and 8 indicate that computational time and memory increases with the increase in value of initial number of clusters.

Edge detection operators are now applied on the results generated by FCM clustering algorithm in order to enhance the edges and results similar to Fig 6 were obtained. Further Fig 9 shows the computational time of various edge detectors along with K-Means and FCM algorithms. It is clearly visible from the results that edge detection algorithms are computationally more expensive with respect to time but are required to obtain distinct edges for better visibility of classification. Thus it is a trade-off between quality of visibility of output and the computational time.

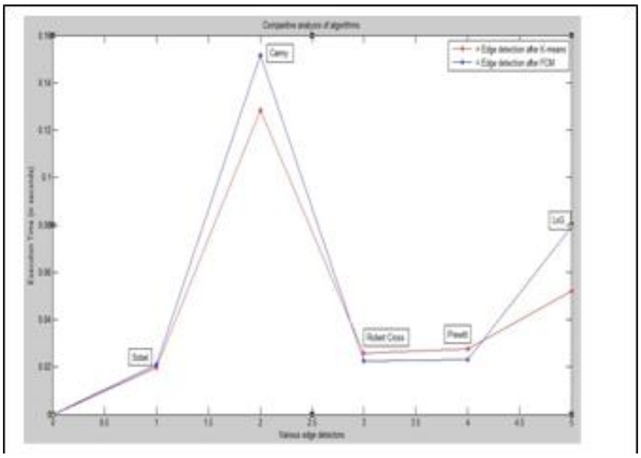

Fig. 9- Computational time of various edge detectors along with K-Means and FCM algorithms

Fig 10 shows the comparative performances of K-Means and FCM clustering algorithms for K=2,3,4 with respect to computational time and Fig 11 compares both the algorithms

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in terms of allocated memory. It can be observed that computational time for K-Means algorithm is much more than that of FCM in all cases. However, FCM algorithm consumes more memory than K-Means algorithm for the considered values of K.

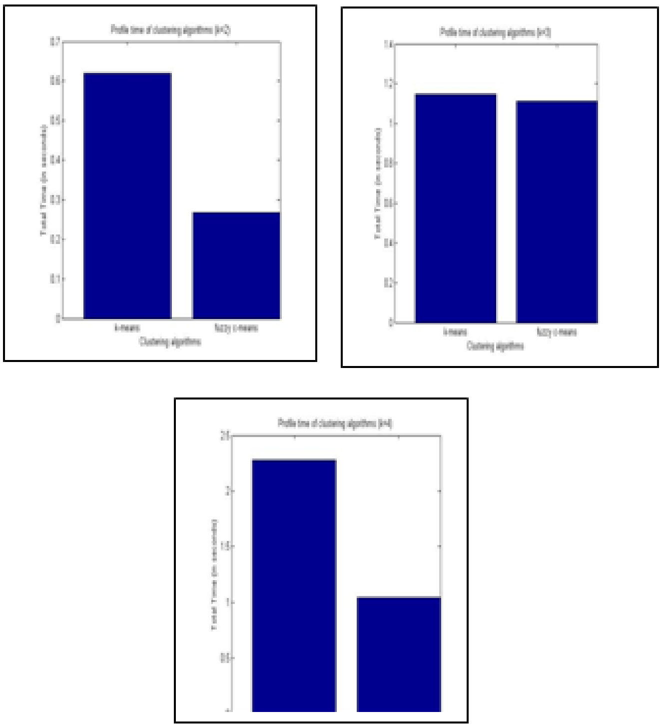

Fig. 10- Computational time for K Means and Fuzzy C-Means

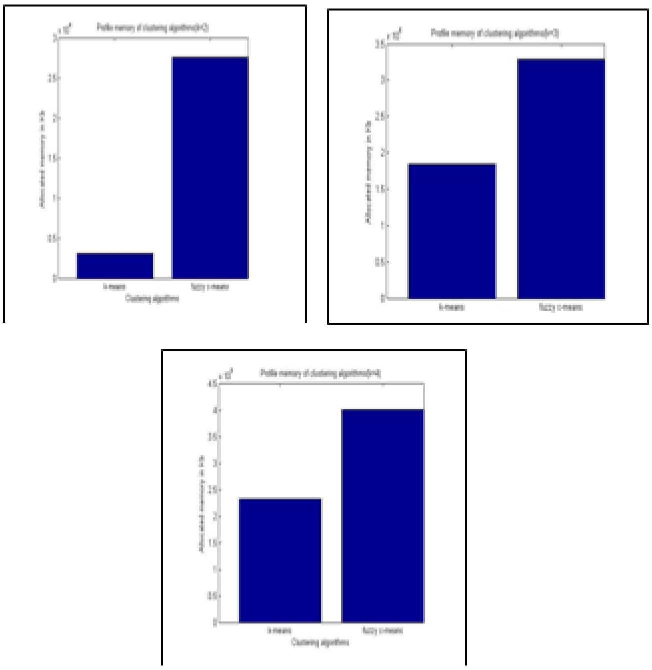

Fig. 11- Memory allocation for K-Means and fuzzy C-means

TABLE 2. - Computational time for various edge detection operators before and after clustering

		Parameter
	Operator Name	Computational Time(s)
Edge Detection Algorithms without clustering	Sobel	0.143024
	Canny	0.305877
	Robert-Cross	0.029104
	Prewitt	0.033437
	LoG	0.038667
Edge Detection after K-Means clustering	Sobel	0.019779
	Canny	0.128444
	Robert-Cross	0.258370
	Prewitt	0.027692
	LoG	0.052214
Edge Detection after FCM clustering	Sobel	0.021003
	Canny	0.151653
	Robert-Cross	0.022607
	Prewitt	0.023081
	LoG	0.079097

TABLE 3. Computational time and memory for various values of k using K-Means and Fuzzy C – Means algorithms.

		Parameters		
		No. of clusters	Computational Time (s)	Memory (kb)
Clustering Algorithm	K-Means Algorithm	K=2	0.62	3176
		K=3	1.51	184558
		K=4	2.28	232460
	Fuzzy C-Means Algorithm	K=2	0.267	27596
		K=3	1.11	329100
		K=4	1.044	401256

VI. CONCLUSION AND SCOPE FOR FURTHER WORK

The experiments are conducted for various set of input images which has different features. The experiments indicate classification of satellite images with and without edge detection operators. The results indicate that the value of k depends on the features of the input image considered for classification. The results also show that k means clustering algorithms are computationally expensive than Fuzzy C means algorithm. Although the edge detection operation increases the computational complexity, the output images give better visibility of the classification. Hence it is a trade of between computational complexity and the visibility of the edges of output image.
Choosing the optimum value of k is very difficult for a given image. If it is possible to obtain the value ok k by mathematical computations, then the clustering can be done more effectively with less computational time and memory. Further, different algorithms can be compared based on other

parameters like accuracy, precision, sensitivity and specificity using a ground truth image.

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